ORCHARD REJUVENATION IN SOUTHEASTERN OHIO

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JULY, 1916

BULLETIN 301

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[1]In cooperation with the College of Agriculture, Ohio State University, Columbus.
[2]On leave of absence.
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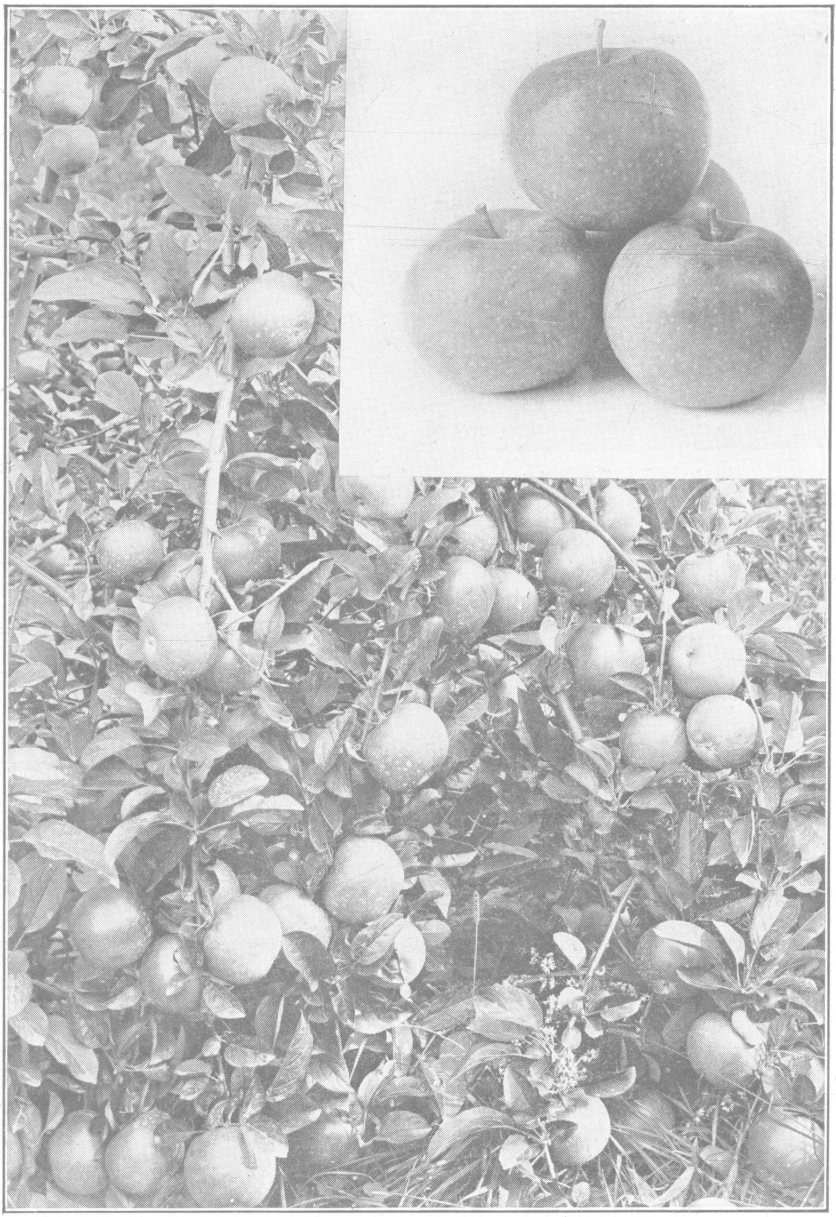
TABLE OF CONTENTS



Marvelous results were secured from this first effort at insect and fungus control under southeastern Ohio conditions.

BULLETIN
OF THE
Ohio Agricultural Experiment Station
NUMBER 301 JULY, 1916

ORCHARD REJUVENATION IN SOUTHEASTERN OHIO[1]

F. H. BALLOU
INTRODUCTION BY W. J. GREEN

The orchard work in southeastern Ohio was begun mainly for the purpose of demonstrating the necessity of spraying apple trees. Experimental work was then considered secondary. Seemingly that section had not profited greatly by the experiments and demonstrations which had been carried on for some time by the Agricultural Experiment Station in various parts of the State. It was well known before work was begun there that the orchards were thought by many not to be of sufficient value to warrant the expenditure of much effort and means to bring them back to their former condition of usefulness.

It was argued by some that the Rome Beauty, which is the principal variety grown there, had run out, and by others that the only thing needed was to spray the trees. Orchard rejuvenation, in its full sense, was not thought of at first. The campaign, as started at first, did not include much more than pruning and spraying. F. H. Ballou has described the successive steps taken and the discoveries made regarding the needs of the trees in the way of plant food. He has also shown that the means are at hand to carry out a complete scheme of orchard rejuvenation in that region. It may seem that the results he secured in Washington and Athens Counties carry lessons of value mostly, if not altogether, to the hill regions of the State. The work of E. J. Riggs and George Walker, of this department, carried on in other parts of the State, shows that orchards on poor hill lands are not the only ones that need

[1]The author acknowledges the efficient services of W. F. Kampf and I P. Lewis of the Horticultural Department, whose assistance in field and record work rendered possible the accumulation of data recorded in this report; also the ever prompt and helpful services of the cooperating orchard owners, J. E. Fultz and son, of Athens County; J. M. Walker and son, S. L. Canfield and M. H. Dyar and son, of Washington County; and C D. Steede and C. F. Higginbotham, resident managers of the Benedict and Porter farms, of Washington and Muskingum Counties, respectively.

rejuvenation, and further that the same principles apply far more widely than has been supposed. Moreover, it is not a premature announcement to say that chemical fertilizers have a place in orcharding, even in comparatively thrifty orchards.

It is possible to use grasses and clovers continuously in orchards as cover crops, by stimulating their growth by means of chemical fertilizers, with advantage to the trees on poor soils. On fertile soils the advantage is less apparent, but even in this case the growth of material for mulching is good economy because the result is fully equal to that of the best methods of culture and the growing of cover crops. The possibilities of grass culture in orchards, combined with mulching, have been greatly increased and the necessity of orchard cultivation has been much lessened. There is now opened to orchardists a freer choice as to methods to be used in both the rejuvenation and the maintenance of apple orchards.

The importance of this will be seen when it is remembered that the fruit on apple trees in grass, and well mulched, is more highly colored than that produced by trees under cultivation. This fact points out one way to meet competition in the markets. It is generally conceded that marketing problems are difficult of solution and that the production of fine fruit greatly lessens the task of selling. Orchard mulching has decided advantages in certain particulars, but the growing of mulching material in the orchard with the aid of fertilizers is a more distinct and decided step in advance because of its greater practicability and wider application as well as its bearing upon marketing problems.

It must now become apparent that the results of the orchard work in southeastern Ohio have more than a local value. Methods must always be chosen to fit local conditions, but it does not follow that because a method is of special value in one case that it is worthless in another.

It will cost orchardists but little to make a trial of the plans of fertilizing the grass in an orchard as well as the trees. There can be no doubt but that it is safe to make the trial on any orchard, but in some cases full results need not be expected for 2 or 3 years. Under the system of intensive orcharding it is one of the operations which seems to be promising.

THE RECOVERY OF A PRACTICALLY LOST INDUSTRY

The scene of operation.—Seven years have elapsed since the writer was commissioned to visit certain discouraged correspondents of the Ohio Experiment Station—owners of apple orchards—located in or near the valley of the Ohio River, in the vicinity of

Marietta, Belpre and Little Hocking, Washington County. The purpose of this visit, which was made in the latter half of April, 1909, was to determine if possible why this particular part of southeastern Ohio, formerly noted for its heavy production of excellent apples and for its extensive shipment of these to markets of the South, was no longer succeeding in this once thriving and profitable industry.

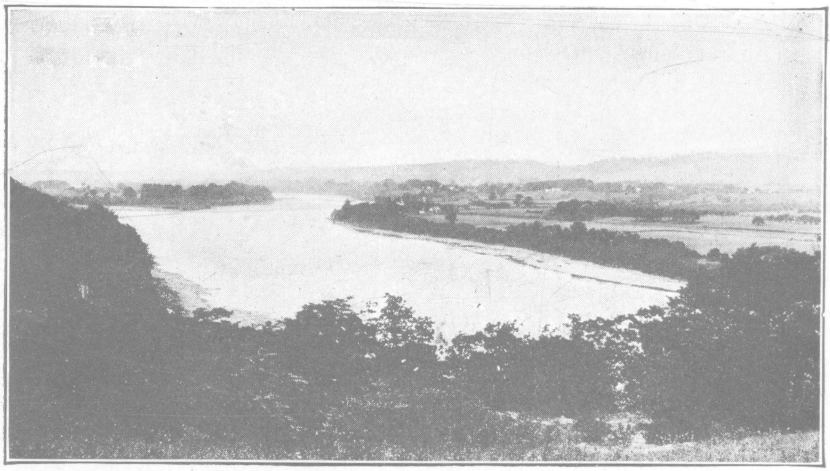


Fig. 1.—The birth-section of Ohio horticulture. View down the valley of the Ohio River from a point opposite Belpre. Head of historic Blennerhasset Island in the distance at left.

Nature had staged a beautiful, inspiring and memorable exhibit for the occasion of our first visit to the pioneer orchard area of Ohio. On hill and in valley hundreds of neglected though not generally unsightly apple orchards, varying in age from 12 to 50 years or more, were just breaking into bloom—the white and pink of the blossoms blending pleasingly with the fresh green of the newly unfolding foliage. Fragrance of apple blossoms was everywhere—seemingly a component part of the very atmosphere of this charming section of the Ohio valley—the birth-section of the horticultural industry of our State. To one accustomed to the more strictly agricultural sections of central and north-central Ohio, this general prevalence of apple orchards ranging in area from 2 to 10 acres or more, was at once a revelation, delight and inspiration.

It was difficult to believe, however, that these orchards so prolific in blossoms and so rich in promise at this season were, in reality, the deceptive, sterile, disappointing plantations so gloomily

portrayed in the correspondence of their owners. Yet from numerous sources, other than the former apple growers themselves, came the testimony that this wonderful florescence was but a misleading demonstration of annual recurrence—a stereotyped promise made by nature in early springtime only to be broken by failure of performance in fruitful results at harvest time. To a student and lover of nature such sentiment possessed an element of discordance at variance with ardent belief and abundant faith that nature is as true as she is comely, if she has our loyal cooperation in counterbalancing the influences set in motion by the disturbing hand of civilization.

Fig. 2.—Hill orchards near Little Hocking.

As the various orchards and orchard owners were viewed and interviewed, the truth steadily unfolded to comprehension, rendering at least the more readily interpreted phases of their problems subject to definite consideration and alleviative action. Simultaneously there developed a clearly defined perception of what might be done for these people who, formerly successful in apple production, were now perplexed and discouraged beyond measure.

Chief among their problems, it was quite apparent, was the grevious scourge of insect pests and fungous diseases to which trees and fruits are subject. These destructive forces were entirely unrecognized and uncombated, and the ever-increasing havoc wrought by them was attributed to late spring frosts, cold winds and rains, river fogs and smoke from river steamboats and from railway locomotives. There was also a somewhat generally prevailing belief

that the climate of southeastern Ohio, at first so propitious for fruit production, had so changed with the passing years, that orcharding could no longer be counted among the profitable industries of the section.

While hurried inspection and study of conditions had been in progress, the orchards of southeastern Ohio had attained full flower. Here and there the petals of the blossoms first to open were beginning to fall—silent but impressive signals to the trained orchardist of the rapidly approaching period at which a fruitful season depends upon his promptness, skill, industry and persistence as a co-worker with nature.

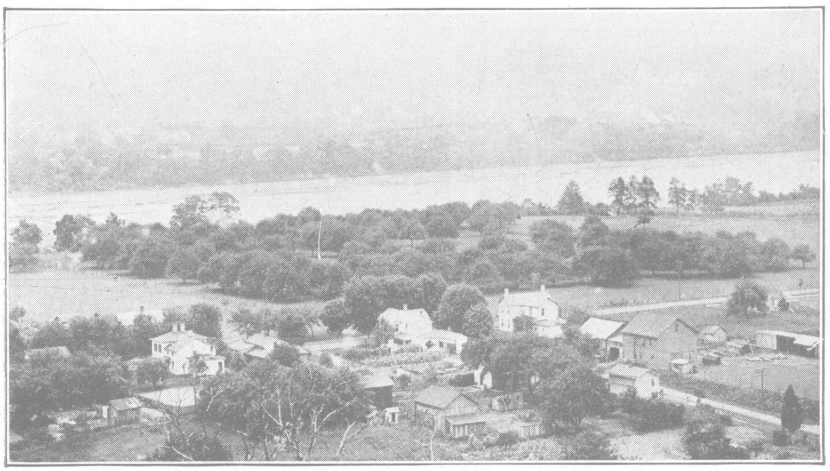


Fig. 3.—A noted orchard of Roxbury Russet at Belpre, in the valley of the Ohio River.

Spraying demonstrations.—In the meantime a written report had been dispatched to the Horticultural Department of the Experiment Station, in response to which directions were at once telegraphed to a manufacturer to rush to the department representative in Washington County, two complete, barrel-type spraying outfits. These outfits, as well as a supply of spraying chemicals from the department, arrived at their destination in good time—just at the close of the period of apple bloom, when the last blossoms were shedding their petals; and the first effective spraying with modern equipment and proper materials that was ever done in southern Washington County was soon in progress. A number of carefully planned experimental plots in three different orchards, located in the vicinity of Belpre and Little Hocking, were sprayed three times

during the season of 1909. Marvelous results were secured from this first effort at insect and fungus control under southeastern Ohio conditions, sound, perfect, beautiful apples in generous abundance being produced, much to the surprise and delight of the orchard owners and their neighbors.

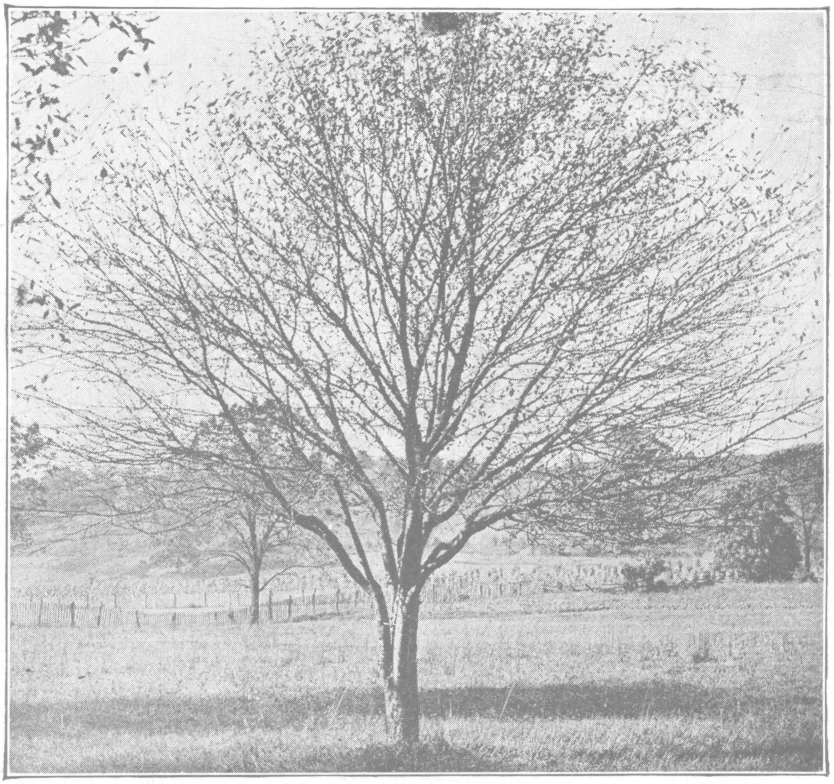


Fig. 4.—Rome Beauty tree almost defoliated by apple-scab fungus; fruit entirely destroyed by fungi and insects (Sept. 1909)

As in the dozen or more years preceding this introductory spraying test, no apples of salable or usable quality were obtained from the unsprayed plots left for comparison; the unsprayed fruit, as usual, throughout the vicinity, was extremely deformed, dwarfed, roughened and blackened by severe infestation and infection of curculios, codling worms, scab fungus and sooty blotch.

These object lessons constituted a most wonderful revelation to scores of orchard owners who, during and at the close of the

growing season of 1909, visited the test plots to observe results and obtain information that would enable them to begin effective work in their own orchards in the spring of 1910.

Spraying only a partial remedy.—During the first season of the Experiment Station's modest beginning in the work of orchard reclamation in Washington County, by the introduction of spraying in 1909, considerable time was devoted to further investigation and

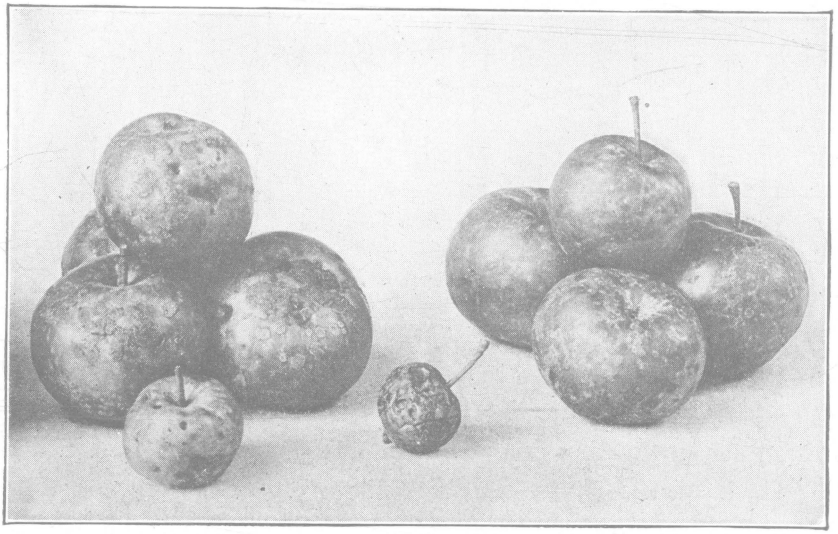


Fig. 5.—Rome Beauty apples dwarfed in size, roughened and discolored by scab fungus and sooty blotch

study of conditions relating to orchard rejuvenation in general throughout that section. It must be admitted that this study revealed the truth that insect and fungus control, while fundamentally and vitally important, was by no means a panacea for the horticultural problems existing in this area of Ohio, which, for a century or more, had been cleared of its virgin growth and subjected to cultivation without due regard to conservation of the soil or its fertility. Especially in the upland and hilly sections bordering the valleys of the Ohio and Muskingum Rivers, were discovered conditions exceedingly discouraging to the many orchard owners (and farmers as well). Here the plow-worn, overcropped, rain-washed hill-slopes were in many cases so depleted of soil, humus and fertility that the orchards, dwarfed in growth, scantily clad with small foliage of a yellowish-green, sickly color, were merely existing. In these orchards spraying, no matter how thorough, could meet the

exigencies of the situation only in small measure. Here, indeed, were opportunities for experimental work where the issues of soil improvement and orchard rejuvenation were involved. This complicated problem, from the horticultural viewpoint, was a novel one. No one knew what would be the outcome because no experimental work under such unpromising conditions had ever been undertaken in Ohio.

Orchard starvation.—Cultivation of the hilly, steep orchard areas of southeastern Ohio, as a general proposition, could not be considered; for these hill-slopes through several generations of thoughtless tillage and farm crop production had been largely denuded of their veneering of productive soil. This soil is today spread over certain portions of the level areas of the valleys of the Ohio and Muskingum Rivers, and is under a high state of cultivation in profitable production of farm and truck crops by the prosperous growers who are owners of valley land and homes. It is a common occurrence to find the original sandy or gravelly soil of the low land overlaid in places with 6 to 12 inches or more of loam or clay soil washed from the cultivated fields of the hilly farms back from the river. These tangible deposits of the cream of the soil of the overtilled hillsides are only slightly suggestive of the untold millions of tons of similar soil that, mixed with soils from elsewhere, now lies in the valley or delta of the Mississippi and on the bottom of the Gulf of Mexico.

Mulching the orchard.—In the spring of 1910 the Horticultural Department was prepared to extend its operations in orchard rejuvenation work in southeastern Ohio. Elementary demonstrations in spraying were discontinued and regular experiments substituted in which different spray mixtures were tested. (See Ohio Agr. Exp. Sta. Bul. 224.) Experiments in mulching the trees with straw or other vegetable matter in connection with the use of chemical or commercial elements of plant food, were inaugurated in a number of neglected and starving orchards on thin and impoverished, upland soils. Mulching in this section, it must be admitted, was, from the outset, a discouraging proposition, because of the expensive and, in many places, difficult transportation of straw. Yet the extreme need of humus, or vegetable matter, within or upon the surface of the hard, lifeless soil of the poor orchard areas covered only with a very light, scattering growth of mixed weeds and poverty grass, seemed to render necessary the purchase of straw or other vegetable substance from outside sources. But the problem of the source of mulch material even for the poorest orchard

soils, as will become apparent later on in this bulletin, was destined to be solved simultaneously with that of the restoration of starving, devitalized, sterile trees to vigor and fruitfulness by the proper use of chemical plant food.

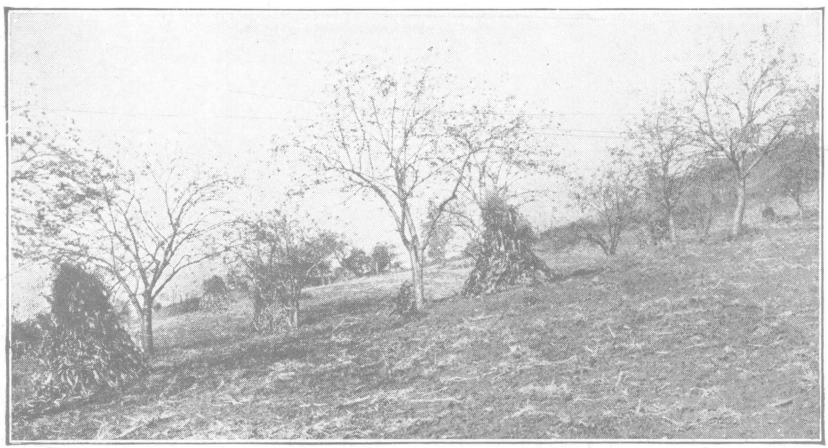


Fig. 6.—An orchard starving because thoughtless tillage and crop production have denuded the hill-slopes of their original productive soil

Well-fed trees more resistant to frost.—The season of 1910 in southeastern Ohio was remarkable from the fact that the prolonged period of summerlike weather in March caused an abnormally early season of bloom in the orchards. The earlier flowering varieties of apples were freely coming into bloom on the 7th of April, at which time the weather turned quite cold. There was a severe frost on the night of the 7th, with the mercury well below the freezing point. Foliage and growing shoots of the more tender species of trees and shrubs were frozen back, while many garden plants and hundreds of acres of early potato plants were cut to the ground. Apple blossoms were seriously injured except on well nourished trees. These suffered but little. Another hard frost with temperature considerably below freezing, occurred on May 5, at which time the young apples which had escaped the April freeze were as large as wren's eggs. A further loss of the crop of 1910 was therefore sustained from this especially trying degree of cold, the fruit being almost wholly destroyed even on the higher elevations, where but a moderate vigor and corresponding somewhat light clothing of foliage afforded insufficient resistance and protection. The better-nourished trees and orchards, however, as

indicated by their more abundant and darker green foliage, throughout southeastern Ohio, where thoroughly sprayed, perfected generous crops of exceptionally good apples, both on the upland and in the valley of the Ohio River.

The season of 1910, therefore, while discouraging to many who sprayed for the first time and failed to secure apples because of poor soil conditions and lack of vigor and resistance of their trees, was an ideal one in demonstration of the remarkable difference in powers of withstanding hardship, between orchards well fed and orchards languishing for want of plant food. These lessons were still further emphasized in many cases where individual trees, groups of trees, rows or parts of rows of trees here and there in otherwise devitalized and fruitless orchards, bore heavy crops of fine apples. Invariably such trees were found to be benefiting by some particularly favorable condition of location—such as proximity to driveways or fencerows which had never been subjected to tillage and cropping, or even to small ravines, small, stony, rough, untillable areas, piles of stones or long neglected and decaying brush-heaps. Note was made of these striking illustrations of the advantages possessed by soil well supplied with plant food as compared with ground depleted of its humus and fertility by a long period of tillage and cropping; and the attention of orchard owners was directed to the valuable object lessons of this nature. These demonstrations were so clear cut and readily interpreted that their significance was quickly and permanently established in the minds of the newly awakened apple growers, splendidly paving the way to intelligent understanding and appreciation of the marvelous results which were to appear the following season of 1911, from the use of chemical plant food applied in 1910.

Early work in orchard fertilization.—The orchards in which the experiments were established were chosen because of fairly even stands of Rome Beauty trees, which were from 17 to 20 years of age and existing on as uniformly poor, thin, upland soil as could be found. The many plots to which various elements of chemical plant food were applied alone and in combination, together with intervening plots left unfertilized for comparison, were under close observation throughout the season of 1910, the initial season of treatment. Nitrate of soda, acid phosphate and muriate of potash applied about each tree, over a circular area slightly larger than that covered by the spread of its branches, at the rate of 5½ and 2½ pounds per tree, respectively, whether used alone or in combination, were the chemical carriers of plant food principally employed. In a part of

this work each tree, earlier in the season, had been mulched with one bale of straw spread in a circle under the outer extremities of its branches. The fertilized and unfertilized plots crossed the mulched plots at right angles, the chemicals, on the latter, being scattered on the mulch. The first application of fertilizers was made the second week in May and, fortunately, was followed immediately by a soaking rain.

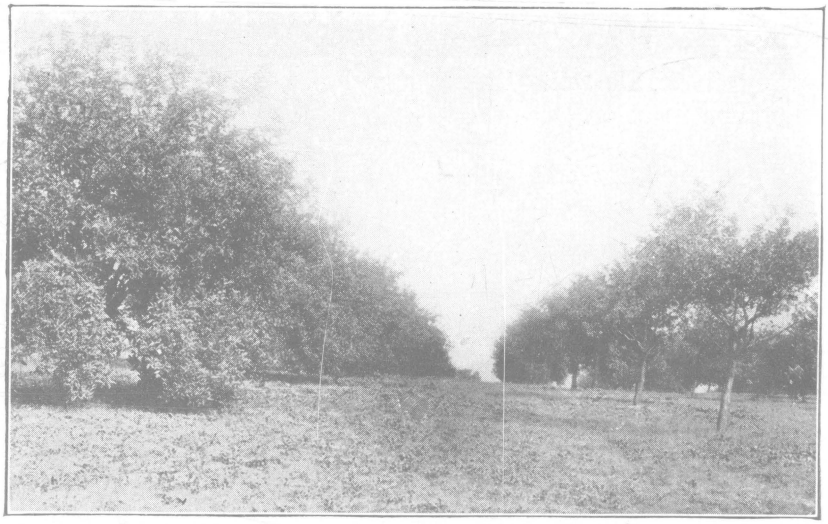


Fig. 7.—Two rows of Rome Beauty trees of the same age. The row at the left stands close to an old fencerow; the one at the right is in the open where tillage and cropping have been followed for generations.

Within 2 weeks the plots of trees to which nitrate of soda had been applied, either alone or mixed with acid phosphate and muriate of potash, were showing greatly improved color of foliage—the leaves being dark green in color as compared with the light yellowish-green of the foliage of the untreated plots. This striking contrast increased as the season advanced; and, at the close of the growing period, the trees of the nitrated plots were thicky filled with conspicuous, plump, healthy fruit buds. But few fruit buds formed on the unfertilized trees, and these were small, slender and unpromising. Plots in two of the three separate, upland orchards in which fertilization work was started, were fertilized with a mulch of stable manure applied early in the spring of 1910; but no evidence of benefit to the trees was apparent the first season (and but

slight evidence of beneficial effect the second season) from this application. Mulching and fertilization of all the test plots were repeated in the seasons of 1911 and 1912.

In 1911 and again in 1912 wonderfully fruitful results were obtained from the plots in all orchards on which nitrate of soda had been applied, while the unfertilized plots of trees remained comparatively weak and sterile. The renewed vigor of the nitrated trees was remarkable; the wood growth which had been unusually short, weak and puny for several years preceding the beginning of fertilization work, became quite equal to that of healthy young trees growing on fertile soil. The foliage had become large, dense and dark green in color.

Fig. 8.—Busy season in a hillside orchard in Washington County, after the revival of the industry.

A reviving industry.—The demonstrations of largely increased fruit production and profitableness from the use of chemical fertilizers on the poor, thin orchard soils of southeastern Ohio, as observed in the seasons of 1911 and 1912, were no less surprising and pleasing to the orchard owners of that section than had been the splendid returns from the Experiment Station's introductory work in spraying in 1909. Spraying, in the meantime, had become quite

generally practiced among the more interested orchardists. The apple-growing industry which was conceded by the residents themselves to have become depressed to the lowest possible level during the preceding 12 years or more, almost miraculously revived and quickly advanced to its rightful place among the leading industrial activities of the rural sections. The extent of this reawakening and the momentum of progress promptly attained by the hitherto discouraged and inactive orchard owners, after they had witnessed the results of thorough and timely spraying, may be realized more readily when it is stated that the financial income from sprayed orchards in Washington County alone, in the seasons of 1910, 1911 and 1912, was $415,000. Notwithstanding the almost total loss of

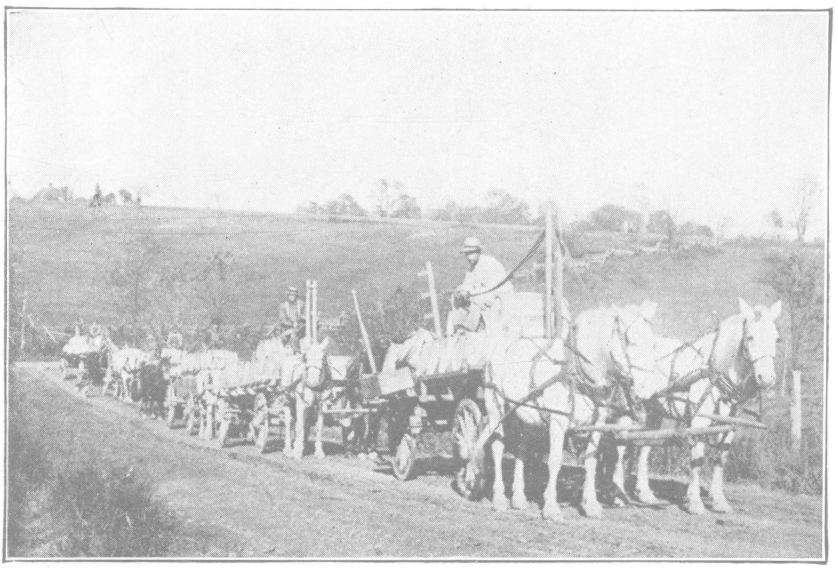


Fig. 9.—Wagons heavily laden with apples on their way to the shipping station at Vincent, Washington County. Before 1909 in this section not enough apples were grown for home use.

the crop in 1913 by severe freezing weather in May, against which growing fruit—no matter how well nourished—could not offer effective resistance, the income, very conservatively estimated, up to the close of the year 1915, has been not less than three-quarters of a million dollars to the county; and the improvement is only beginning.

Production of mulch material.—In contrast to the excellent results in improvement and maintenance of tree growth and fruitfulness from the practice of mulching apple trees with straw in central and northern Ohio, in the so-called sod-mulch plan of orchard culture, it was somewhat surprising not to note any clearly marked benefit from application of the straw mulch alone, about trees existing on the thin, compact, lifeless soils in southeastern Ohio. In 3 years' mulching with straw at Fleming and New Matamoras, Washington County, and Torch, Athens County, there did not appear evidence of sufficient additional benefit from this very expensive and inconvenient practice, compared with the plots fertilized without mulching, to warrant its continuance.

This statement, however, is not a condemnation of the excellent plan of maintaining a mulch of vegetable matter about the trees or over the entire surface of the orchard area; for an unexpected result had come about wherever nitrogenous fertilizers were used around unmulched trees: A wonderfully dense and heavy growth of the better grasses, after the first season's fertilization, had sprung up in broad circles immediately around the fertilized trees; and the bulk and weight of this new growth of vegetation which, encircling each tree where only a very light and thin covering of weeds and poverty grass had before existed, were not far short of the bulk and weight of the quantity of straw that, because of high price and difficulty of obtaining it in that hilly country, could be afforded to apply as a mulch. Moreover, the mulch of mixed grasses, in value of manurial constituents, is just about double that of the wheat straw.

A fairly liberal mulch was therefore being supplied from annual clippings of grass, where fertilizers alone were being applied. Here, indeed, was a suggestion directly from nature herself, which, properly interpreted and acted upon, promised to solve the perplexing problem of the source of mulch material and humus. The course to be followed was clearly apparent; viz, to increase slightly the quantity of fertilizer per tree, applying it evenly and entirely over the surface of the square of ground occupied by each tree, instead of over a restricted, circular area beneath the outer extremities of its branches. In this connection it will be well for the reader to bear in mind that apple trees on this extremely poor, upland soil, even at the age of 20 to 25 years, are generally so small compared with trees of similar age growing on stronger land, that they, at the beginning of the work of rejuvenation, exert but little restrictive effect upon the quantity of vegetation that can be grown for mulch on the orchard area by fertilization.

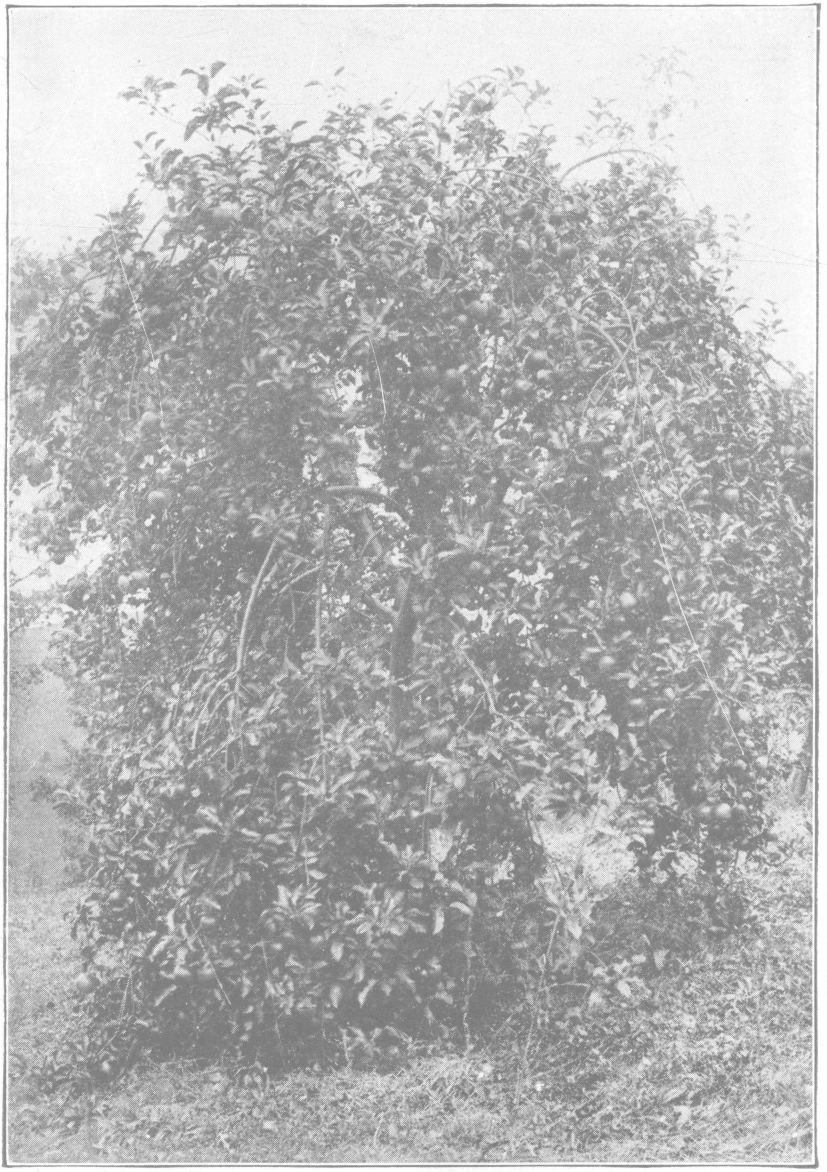


Fig. 10.—A Rome Beauty tree which for 20 years was starved and fruitless is now vigorous and productive from fertilization with nitrate of soda and acid phosphate.

Fortunately a small experiment with somewhat heavier, "all-over" fertilization on very poor land, had been started at Hopewell, Muskingum County, in the spring of 1909, where the plots on which a nitrogenous combination of fertilizers had almost immediately begun to produce an abundance of good mulch material—all that could be desired for a soil covering even where such extreme conditions of soil poverty existed as had prevailed at this point.

Additional experiments in orchard fertilization and production of mulch material in the orchard, were begun in 1912 in an orchard occupying the level summit of a high bluff overlooking the valley of the Muskingum River, 3 miles below Lowell and 7 miles above Marietta. At this point there have been and continue to be obtained especially interesting and helpful results, a partial report of which is included on other pages of this bulletin. Unusually interesting orchard fertilization and culture work also has been in progress near Vincent, Washington County, which was begun in the spring of 1914.[1]

LATER EXPERIMENTS IN ORCHARD FERTILIZATION

Nitrogen deficiency confirmed.—The completion of a 5-year period of work in orchard fertilization at three different locations in southeastern Ohio has only confirmed our former reports that the thin upland soils of central, eastern and southern Ohio are seriously deficient in nitrogen; and that the application of readily available nitrogen where such soil conditions exist surprisingly transforms starving, unproductive orchards into those that are vigorous, productive and profitable. In this most wonderful change brought about by the use of nitrate of soda as the promptly available source of nitrogen, there has appeared within the 5 years but little evidence of additional benefit derived when acid phosphate and muriate of potash, as sources of phosphorus and potassium, have been combined with nitrate of soda—so far as tree growth, or yield, appearance or texture of fruit is concerned. However, there have appeared strong indications of the beneficial effect of acid phosphate in an entirely unlooked-for way—a surprising development that will be discussed later on in this report.

[1]Details of the work summarized in the foregoing pages are given in Ohio Agr Exp. Sta Buls 217 24 and 240.

Fig. 11.—Production in 1911 of two rows of Rome Beauty containing 12 trees each. Row at left, fertilized in 1910 with 5 pounds each of nitrate of soda and acid phosphate per tree, produced 30 barrels. Row at right, unfertilized, produced 3 barrels. Trees of both rows had same care in mulching and spraying.

Fig. 12.—Production of same two rows in 1912, same treatment having been continued as was given in 1910. Yield of fertilized row 20 barrels; of unfertilized row 7 barrels.

AVERAGE ANNUAL RESULTS FROM FERTILIZER TESTS IN ATHENS AND WASHINGTON COUNTIES

Owner	Plot	Fertilizer treatment per tree	Average yield per tree	Average gain per tree	Average gain per acre		Value of increase per acre	Cost of increase per acre	Net increase per acre
		Pounds	Pounds	Pounds	Pounds	Barrels	Dollars	Dollars	Dollars
J. E. Fultz	1	Nitrate soda 5 lb.	315.6	245.7	9828	67.7	169.25	6.00	163.25
	3	Nitrate soda 5 lb.; acid phosphate 5 lb.; muriate potash 2½ lb.	205.8	135.9	5436	37.4	93.50	10.00	83.50
	5	Tankage 5 lb.; bone 5 lb.; muriate potash 5 lb.	93 8	23.9	956	6.5	16.25	8.00	8.25
	7	Nitrate soda 5 lb.; acid phosphate 5 lb.	214.2	144.3	5772	39.8	99.50	8.00	91.50
	9	Muriate potash 5 lb.	96.0	26.1	1044	7.2	18.00	2.50	15.50
	11	Stable manure 250 lb.	100.1	30.2	1208	8.3	20.75	(*)	20.75
	Checks	....	69.9	....	....	....	....	....	....
J. M. Walker	1	Stable manure 250 lb.	284.7	160.6	6424	44.3	110.75	(*)	110.75
	3	Nitrate soda 5 lb.	296.3	172.2	6888	47.5	118.75	6.00	112.75
	5	Nitrate soda 5 lb.; acid phosphate 5 lb.; muriate potash 2½ lb.	317.6	193.5	7740	53.3	133.25	10.00	123.25
	7	Tankage 5 lb.; bone 5 lb.; muriate potash 2½ lb.	163.9	39.8	1592	10.9	27.25	8.00	19.25
	9	Muriate potash 5 lb.	133.7	9.6	384	2.6	6.50	2.50	4.00
	Checks	....	124.1	....	....	....	....	....	....
S. L. Canfield	1	Nitrate soda 5 lb.	378.9	256.3	10252	70.7	176.75	6.00	170.75
	2	Nitrate soda 5 lb.; acid phosphate 5 lb.; muriate potash 2½ lb.	348.4	225.8	9032	62.2	155.50	10.00	145.50
	3	Same as Plot 2	315.9	193.3	7732	53.3	133.25	10.00	123.25
	Check	....	122.6	....	....	....	....	....	....

*No charge for manure or cartage.

Striking similarity of results in three different orchards.—Plots on which nitrate of soda (5 pounds per tree, scattered in a circle beneath the outer extremities of the branches) was used, either alone or in combination with other chemical elements of plant food, returned an average cash gain per acre annually, for the 5-year period, as recorded below:

Orchard of J. E. Fultz, Torch, Athens County.....$112.75
Orchard of John M. Walker, New Matamoras, Washington County.... $118.00
Orchard of S. L. Canfield, Fleming, Washington County..... 146.50

During this period of 5 years' work, on account of the freezing weather of May, 1913, the crop for that year in all our experimental plots, as well as in most of the orchards in central and southeastern Ohio, was totally destroyed. Therefore the gain recorded in the foregoing statement, for each series of plots, is in reality that from four crops produced in 5 years—which is not a bad record for orchards which practically had been abandoned for years and considered as farm encumbrances rather than possible sources of profit.

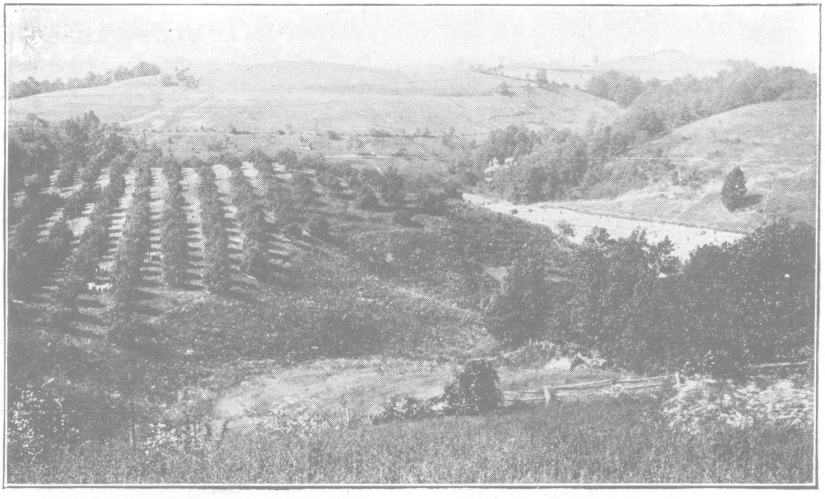


Fig. 13.—Walker orchard and surrounding hills, typical of southeastern Ohio.

Negative results from use of acid phosphate in apple production.—Only in the Walker orchard did the use of acid phosphate (with potash) in combination with nitrate of soda indicate any advantage in fruit production over the use of nitrate alone; and whether this small gain was due to acid phosphate more than to the potash, or whether it was due alone to a quite possible slight variation in soil conditions, cannot be determined. In this case the plot

treated with the complete mixture gave a gain of $10.50 per acre annually for 5 years, over the plot on which the nitrate alone was used. At Fleming and Torch the gains for the 5-year period were considerably greater where the nitrate was used alone than where the complete combination was applied; but, in both of these cases, in planning the experimental work, it so happened that the nitrate rows were at or near the margin of the orchard where soil conditions are not infrequently somewhat more favorable than those of the general orchard area.

No clearly defined benefit from potash.—While the use of potash alone in the work recently concluded at no time presented to the eye visible evidence of any benefit to tree or fruit, as compared with the unfertilized plots, yet the record of yields for 5 years in the Walker and Fultz orchards seems to indicate a slight margin of gain. However, this apparent increase from potash, unlike the heavy, uniform, unmistakable gains from the use of nitrate of soda wherever applied, was relatively both so slight and so variable throughout the 5-year period, that we cannot reasonably conclude that it really had any bearing at all upon the final results. As compared with the average yields from check or unfertilized plots, those treated with potash alone gave as an average per acre annually for the 5-year period, the following results:

In the orchard of J. E. Fultz, at Torch, Athens County, a cash gain of $15.50 was realized, while in the orchard of J. M. Walker, at New Matamoras, Washington County, a gain of $4 was obtained.

A potash-treated plot, together with a bone-and-tankage-treated plot, was originally included in the Canfield orchard experiment at Fleming, Washington County; but these made such an extremely poor showing in comparison with the nitrate-treated plots that they, at the desire of the owner, were turned over to him to be fertilized with a nitrate of soda combination.

The comparatively slight variations in yields of the potash-treated plots during the 5 years, under soil conditions as we find them in the average hill orchards of the southern half of Ohio, really indicate nothing worthy of serious consideration; for equally as great variations often occur between different unfertilized plots in the same orchard, as between the potash plots and unfertilized plots.

Wide variation of results from the use of stable manure.—The foregoing tables of yields for the orchards at Torch and New Matamoras show that the plots on which stable manure was used at the rate of 250 to 300 pounds per tree annually applied as a mulch under the circular spread of branches, present results rather puzzling and

difficult of interpretation. At Torch the manure mulch annually applied has given a cash gain of only $20.75 per acre annually for the 5 years, as compared with the unfertilized plots adjoining. At New Matamoras, while not making any beneficial showing in increased fruit production until 2 years after the first application, the plot treated with stable manure (not counting any cost for the manure or cartage) has given in the full period of 5 years the average gain per acre annually of $110.75—or $2 per acre per year less than the adjoining plot treated with nitrate of soda alone. So far as all external appearances indicated, conditions in these two orchards were similar and equally favorable at the outset.

Probable cause of behavior of experimental plots.—It may be well to state that in the three orchards in which we have closed a 5-year period of work, the variety is Rome Beauty; the orchards have been planted from 22 to 25 years, and the soil conditions are probably as nearly uniformly poor as could be found in any three orchards in all southeastern Ohio. However, strange variations in the behavior of trees, plots and small, scattered, irregular areas, are almost certain to appear during a period of careful experimental work, even in the most uniform orchards that it is possible to obtain for such work; and while it is a matter of conjecture as to the cause or causes of this phenomenon, the writer has not the least doubt but that by far the greater number of these puzzling variations are more or less the direct results of the lack of uniform treatment, fertilization and cultural care of these long-tilled areas by the three or four generations of owners who have coaxed or wrested from this land the sustenance of life. Because of these obscure but certainly existing and influential causes of freakish behavior of individual trees, or of rows, parts of rows or sections of orchards embraced within the area in which experiments are being conducted, individual tree records are of no dependable value in determining results. Only averages from rows or plots are worthy of being utilized as the bases for conclusions and for intelligent direction in treating orchards most effectively under the conditions represented.

Nitrate of soda vs. tankage and bone for orchard fertilization.—Early in our orchard-fertilization experiments we began a comparison of the value of nitrate of soda and acid phosphate with that of tankage and bone as sources of nitrogen and phosphorus. The showing made by the tankage and bone has been so inconsiderable, as compared with the nitrate-phosphate combination, as to discourage entirely the use of the former as a surface dressing in orchards cared for under the grass-mulch system of culture. Clearly the

tankage and bone are very slowly soluble unless incorporated with the soil by tillage. In our experiments in the Dyar orchard, near Lowell, Washington County, which now have been in progress for 4 years, the nitrate-phosphate formula has given a clear gain of $86.20 per acre annually in fruit, and an additional gain of $6.32 per acre annually in mulch material from increased grass growth, as compared with the tankage-bone formula.

UNFINISHED WORK

Fertilizers with straw mulch vs. double-rate fertilization without mulch of straw.—Another experiment was started in the Dyar orchard to determine the merits of the usual 5-5-2½ pounds per tree of the nitrate-phosphate-potash combination used in connection with a mulch of one bale of straw per tree, applied annually in a circle under the outer extremities of the branches, compared with a double, or 10-10-5 pounds per tree, mixture of the same chemicals applied evenly over the entire surface of the tree-squares of ground except near the bases of the trees, without a mulch of straw or any additional vegetable matter from outside sources. The chief object of this comparison was to determine whether mulch material for a soil-covering and source of humus can be produced right in the orchard, on very thin, poor soil, by increasing the rate of fertilization and distributing the plant food evenly over the tree-squares, at a price more reasonable than that which we were usually forced to pay for straw in that hilly section where straw, as a rule, is not only scarce and high in price but expensive and difficult to transport considerable distances over the steep, rough roads. The results for the 4 years (three crops of apples) may be stated as follow:

The plot on which the nitrate-phosphate-potash combination has been used with a mulch of straw has returned a cash gain per acre annually for the period named of $92.90, as compared with the adjoining plot on which nothing was applied, while the plot on which the double quantity of the nitrate-phosphate-potash mixture has been applied without mulching, has returned a cash gain per acre annually for the 4 years of $106.40, as compared with the check, or unfertilized plot, or a difference of $13.50 in value of fruit per acre annually in favor of the heavier, "all-over" fertilization without mulching material from outside.

Quantity, cost and manurial value of straw- and grass-mulch compared.—Where the 5-5-2½ formula of chemicals was used with the mulch, the one bale of straw per tree would rarely exceed 80 pounds in weight. The actual manurial value of the 80 pounds of

dry wheat straw is just about 9 cents; yet it cost an average of 40 cents per tree, or $10 per ton, or $16.80 per acre for the 42 trees which in the Dyar orchard occupy an acre of ground. On the plot fertilized with the double weight of chemical plant food without a straw mulch, there has been produced per tree-square per year an average gain of 46.12 pounds of sun-dry mulch material, for the period of 4 years, composed principally of mixed timothy, redtop and bluegrass, as compared with the unfertilized plot. The actual fertilizing value of this 46.12 pounds of mixed grasses is 11.4 cents,

Fig. 14.—Four seasons' fertilization with 5-5-2½ pounds per tree annually of the nitrate-phosphate-potash mixture, and a mulch of one bale of straw per tree annually produced this difference in vigor on trees formerly uniform in size and condition. Figures 15 and 16 show the same orchard.

or 2.4 cents per tree-square more than that of the 80 pounds of wheat straw. While not so great in bulk or weight per tree-square as the one bale of wheat straw, the mixed grasses are much finer for mulching purposes. Another important fact in this connection is that the gain in weight of mixed grasses on the plot receiving the double-weight, all-over fertilization, is that of the single clipping made in June of each season. The grass is cut and allowed to lie and cure where it falls when cut. It is then carefully raked by hand so that no material from former cuttings will be gathered with it. After the product of each tree-square is weighed separately, the grass is then spread back over the surface from which it was cut.

During late summer and throughout autumn, each season, there is a fine, dense, second growth or aftermath which springs up through the decayed and decaying accumulation of former cuttings and aftergrowths. Were it possible to separate and weigh this second, or autumn, growth, the gain in weight of vegetable matter per tree-square per year would be materially increased, and the total value of the orchard-grown mulch material produced from double-rate fertilization would be shown to be far in excess of such a quantity of straw as one could afford to buy and use at the high prices usually prevailing.

The cost of the 46.12 pounds of mixed grasses per tree-square per year, we may concede to be about the 25 cents per tree annually paid for the extra 5-5-2½ pounds of chemicals in the doubled fertilization, which indicates the price of the increased weight of grass-mulch to be $10.80 per ton, or about 80 cents per ton above that which we have repeatedly paid for straw. At the cost of 25 cents per tree the 46.12 pounds gain in grass mulch amounts to $10.50 per acre annually for the 42 trees, as compared with the cost of $16.80 per acre for the 80 pounds per tree of wheat straw. Therefore, on the basis of an acre of 42 trees, the gain of 1,937 pounds per year of grass mulch by double fertilization, has cost $6.30 less than the required 3,360 pounds of straw for one bale per tree annually, while the manurial value of the grass mulch is 84 cents per acre annually greater than that of the straw. Hence, strictly from the viewpoint of maintenance of fertility and gradual betterment of conditions of the orchard soil physically by means of the two schemes of fertilization and mulching just described, we find that we have, at the end of 4 years, a saving (or gain) of $7.14 per acre annually for the double-fertilization, grass-mulch plan. This amount, plus $13.50 actual gain per acre per year in fruit from the grass-mulch method, gives a total gain of $20.64 per acre annually for this combination.

The objection usually urged against the plan of growing mulch material in the orchard is that such a practice draws largely on the moisture content of the soil and that the trees and fruit will suffer in consequence. So far in our work there has been no evidence in support of such a theory; for vigor and growth of trees have been all, and even more at times, than are desirable, while the fruit has attained good size, perfect form and, except where entirely hidden from the sun by the heavy foliage, of good color. The growth of grass takes place early in the season while there is an abundance of moisture in the soil, and is cut in June after which the accumu-

Fig. 15.—Production in 1914 of two rows of Ben Davis containing 12 trees each. Row at left, fertilized in 1912-13-14 with a 5-5-2½ pounds per tree nitrate-phosphate-potash mixture applied in connection with one bale of straw per tree annually, produced 49 barrels of large, marketable apples. Row at right, unfertilized, produced 20 barrels.

Fig. 16.—Production in 1915 of same two rows shown above, same treatment having been continued. Yield of fertilized row 46 barrels; of unfertilized row 9 barrels.

lation of decayed and decaying vegetable matter on the surface conserves the moisture and keeps the soil cool by shading it heavily from the direct rays of the sun.

The straw-mulch and grass-mulch plots vs. unfertilized plots in fruit production.—It may be interesting to note that the double-fertilized, grass-mulch plot, for the 4-year period, has averaged 56.7 pounds per tree-square, 2,381.4 pounds per acre annually, of sundry, mixed timothy, redtop and bluegrass, while the unfertilized plot for the same time has averaged only 10.5 pounds per tree-square, or 441 pounds per acre per year, of the thin, mixed growth of various native weeds and poverty grass which formerly covered the entire orchard area. No seed of any kind has been sown. In yields of fruit per acre per year, for the period of 4 years, we have the following comparison:

RESULTS OF FERTILIZING AND MULCHING

Treatment of plot	Yield	Gain
	Barrels	Barrels
Double-fertilized, grass-mulch	101.7	63.7
Fertilized (5-5-2½), straw-mulch	98.1	60.1
Unfertilized	38.0	.....

Transformation from mixed weeds to fine grasses.—One of the most striking and marvelous results of the repeated use of chemical fertilizers on the plow-worn, overcropped, eroded, thin, orchard soils of the hilly sections of central, eastern and southern Ohio, is that the sparse, almost worthless soil-covering of weeds and poverty grass which almost invariably occupies abandoned orchard areas, is soon replaced by a dense growth of the better and finer grasses which thrive and increase as the seasons pass; and which, annually clipped and permitted to lie on the ground, blanket the almost naked hill-slopes with a covering of decaying vegetable matter. No grass seeds have been sown in bringing about this surprising change. The secret of the amazing transformation is that, scattered among the weeds and poverty grass which nature provides shall spring up and occupy land too deficient in plant food to enable the better grasses to thrive, one may find here and there, by close inspection, weak, struggling plants of timothy, redtop, bluegrass, and white and red clover. These plants are so small, delicate and few in number, in many cases, that a casual observer would scarcely notice them at all. Yet they are ready, when the particular elements of plant food upon which they thrive are supplied to them in

generous measure, to spring promptly and vigorously into growth, and to multiply and thicken and take possession of the ground upon which they previously had been able to maintain but a feeble existence.

Under this treatment of orchard soils it is pleasing to note the ready and generous response of the trees in increased growth, vigor and abundant fruitfulness—a response which enables orchards occupying steep, rough, difficultly tillable land to compete successfully with orchards under annual cultivation with cover crops where tillage may be practiced with ease and satisfaction.

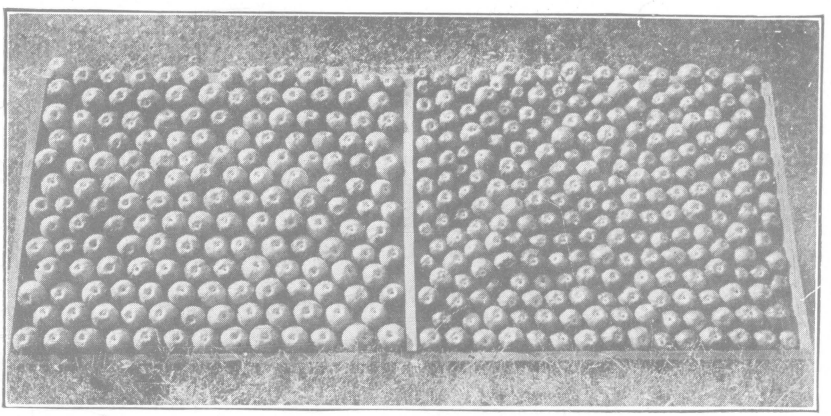


Fig. 17.—"Tree run" Ben Davis apples from fertilized (left) and unfertilized (right) trees in the Dyar orchard. The fertilized tree bore more than 3 barrels; the unfertilized tree in an adjoining row, less than 3 pecks.

How lasting are the effects of nitrate of soda?—The question has occurred repeatedly: How durable are the effects of nitrate of soda as the source of nitrogen, and what would be the results of applying nitrate for one or two seasons and then discontinuing the application for a year or more? We have been endeavoring to work out dependable data on this subject; and considerable information has come to us along this line from unexpected sources. In three different orchards, in May, 1910, we applied to certain plots the 5-5-2½ pounds per tree of the nitrate-phosphate-potash combination which, in 1911, gave us the splendid average gain of 2,893 pounds of apples per plot, as compared with adjoining unfertilized plots. The treatment of these three plots, after the first fertilization in 1910, was then changed to an annual application of 5-5-2½ pounds per tree of the tankage-bone-potash combination, by which change there seemed some reason to hope that we might succeed in

holding the advantage gained from the use of the initial application of the nitrate-phosphate-potash mixture, with the more slowly available and perhaps more durable substances of tankage and bone. The results were disappointing. The remarkable average gain per plot, obtained in 1911 from the initial application of the nitrate combination in 1910, was not approximated by any one of the three yields produced in the 4 years which followed. In actual results it

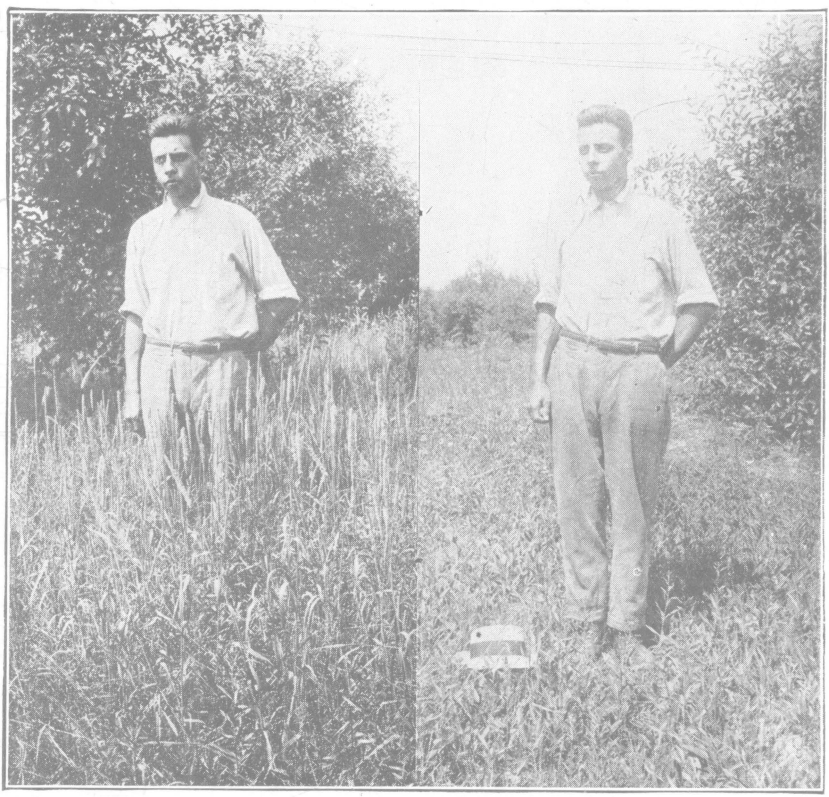


Fig. 18

Generous production of the better grasses for mulching in the double-rate, all-over fertilization.

The scant, weedy growth on the unfertilized plot. The two locations shown here were only 8 feet apart.

may be stated that the average gain from the first nitrate combination treatment of 2,893 pounds of fruit per plot was followed by an average gain per plot annually, for the 4 years, of only 1,406 pounds, or less than half the increase realized the first year, as compared with the same adjoining unfertilized plots.

Similar results from dropping out nitrate are indicated in the Dyar orchard experiments, where only acid phosphate is now being used where the nitrate-phosphate-potash mixture had been applied previously; but not sufficient time has elapsed to justify reporting at this time the figures so far available. It may safely be stated that a single application of nitrate to an orchard on poor soil, if made early in the season, not only will benefit the crop of the current season materially, but will reinvigorate the trees to such an extent that there will be generous and healthy fruit-bud formation for the season following, when the maximum of benefit from the one application will be realized; but the second year following the year of the first and only application, will show a marked decrease

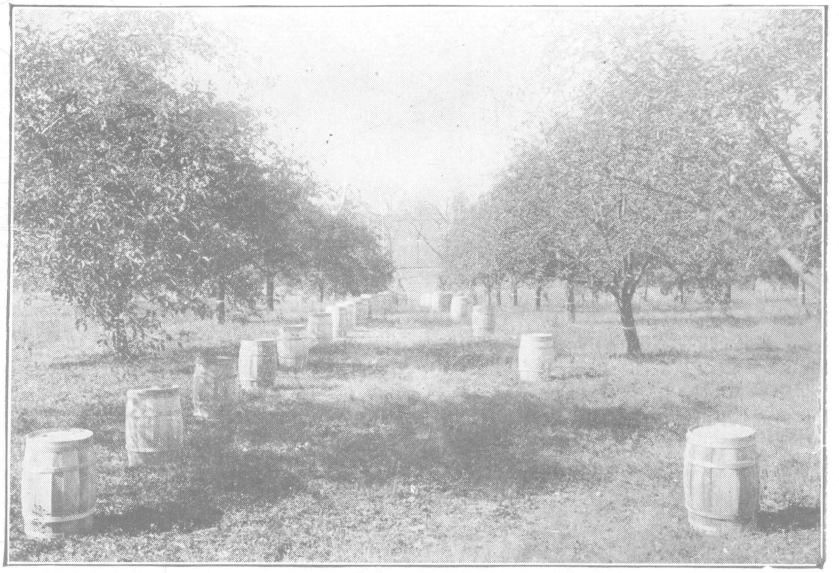


Fig. 19.—Production of two rows of Rome Beauty containing eight trees each (1914). Row at left, fertilized for first time in April, 1914, yielded 21 barrels; row at right, unfertilized, 9 barrels.

in vigor and fruitfulness of the trees. Only when trees under the soil conditions named, by repeated, annual applications of nitrate, begin to evidence by a superabundance of wood growth and of foliage, that they are attaining an excess of vigor, may we safely drop out an occasional season's application of nitrogenous plant food. It is a better plan, when these overvigorous conditions of the trees begin to appear, to lessen the quantity of nitrate annually applied rather than to discontinue its use for a season or two.

The importance of early application of nitrate.—Later additions to our data concerning the use and effects of nitrate of soda have demonstrated that by making the application early in the season—not later than the middle of April—we may obtain distinctly beneficial results in yield of fruit the current year of application, while the trees, no less than from the applications made in May as formerly practiced, are benefited in growth of wood, production of large, healthy, rich dark-green foliage, and in the formation of an abundance of well-developed fruit buds for the succeeding year. In proof of the surprising promptness in obtaining clearly marked, beneficial results from the initial application of quickly available, nitrogenous plant food, if made early in the season, it may be stated that at Vincent, Washington County, early in the year of 1914, our Horticultural Department leased for a 5-year period a small orchard of 140 trees which, although more than 20 years of age, had never produced but one crop of apples—these being imperfect because of injury by insects and fungi. The soil in this orchard was as extremely and uniformly poor as until that time we had been able to find. This orchard was divided into plots for culture and fertilizer experiments, the fertilizing chemicals being applied about the middle of April—just as the pink of the bursting blossom buds was beginning to show. The trees bloomed rather uniformly over the entire orchard, but the blossoms were unusually small and apparently lacking in vitality. However, after the petals of the blossoms had fallen, the little apples on the fertilized plots where nitrate of soda had been included clung to the fruit spurs and began to grow in a perfectly normal manner, while most of the embryo fruits on the adjoining unfertilized plots withered and dropped from the trees just as the apples had been doing throughout the past life of the orchard. From the time of this first application of plant food until this wonderfully marked difference between the fertilized and unfertilized plots became apparent, not more than 3 weeks had elapsed; but the nitrogen had demonstrated its prompt, reinvigorating power by meeting almost immediately the demand for nourishing plant food where tree starvation had so long existed. At the apple harvest of the same season, 1914, we gathered 200 barrels of fine fruit. The plots receiving nitrate of soda, either alone or combined with other elements, exhibited a surprising gain over the adjoining untreated plots of the same varieties. The most marked gain of a fertilized plot over its companion check plot, for this first season's fertilization, was the yield of 21 barrels of Rome Beauty apples from 8 trees in Row No.

13, fertilized with a 5-5 nitrate-phosphate combination applied evenly over each tree-square, as compared with the product of 9 barrels from 8 trees of the same variety in Row No. 14, which stood alongside. This gain of 12 barrels of apples from 8 fertilized trees was realized from the expenditure of $1.60 for fertilizers—a cost of 13.3 cents per barrel. In 1915 these same two plots, fertilized and unfertilized, produced 22.5 barrels and 14.2 barrels, respectively —a gain of 8.3 barrels for the nitrated row for the second season, or a total gain of 20.3 barrels for the 8 trees in the two seasons. The total yield of the Vincent orchard for 1915 was 300 barrels, or 500 barrels for the two seasons that we have had it under control. Prominently located quite near and in plain view of a much traveled public highway, this orchard had for many years been widely known and generally discussed as one that had never been sufficiently productive of apples to supply the farm home near which it is situated.

Phosphorus in orchard fertilization.—Early in this presentation the writer illustrated the apparently negative results thus far obtained, in so far as yield of fruit is concerned, from the use of acid phosphate as the most quickly available source of phosphorus. Mention was made in connection, however, of a surprising and beneficial development that has appeared as the direct result of persistent use of acid phosphate in our orchard fertilizer work. In this connection it will be well to recall, too, what has been stated about plants of various species of the more valuable grasses and clovers which, though thinly scattered, and scarcely noticeable among the native weeds and poverty grass which invariably take possession of the thin, upland soils of neglected orchards and abandoned fields, may be found by searching carefully for them. It has already been stated that the application of plant food rich in quickly available nitrogen causes such plants as timothy, bluegrass, redtop and, in some cases, orchard grass, to spring up and take possession of the ground where before only weeds and poverty grass conspicuously existed, so that the comparatively worthless weed growth will be crowded out. However, where this marvelous development of the better grasses is promoted by the use of plant food rich in nitrogen, the occasional, barely existing, small and weak plants of red and white clover are not noticeably benefited. Indeed, in the experiments which we have had under observation, the vigorous, dense growth of the grasses which delight in an abundant supply of nitrogen has practically crowded and smothered the little clover plants out of existence.

On the other hand, where phosphorus in the form of acid phosphate is use alone or in combination with muriate of potash, there is but slight beneficial effect on the grasses; but the small, scattering clover plants soon begin to increase noticeably in size, spread or multiply, and gradually take possession of the soil. In the fifth season's work in the orchard of Dr. William D. Porter, near Hopewell, Muskingum County, the following interesting development on the various duplicated plots was available for study. The figures given present averages for the duplicated plots:

RESULTS OF FERTILIZERS ON YIELD OF MULCH

Annual fertilizer treatment per acre	Yield	Kind of grass
	Pounds	
Acid phosphate 350 lb.	2,716	Red clover
Acid phosphate 350 lb.; muriate potash 175 lb.	2,884	Red clover
Acid phosphate 350 lb.; muriate potash 175 lb.; nitrate soda 350 lb.	3,458	Timothy, redtop bluegrass, orchard grass
Unfertilized	840	Poverty grass, weeds

A noteworthy point in connection with the range of developments attained during the fifth season's operations in this orchard where soil conditions were extremely and uniformly poor at the beginning in 1909 and where no seed of any kind has been sown and no plowing or disking done, is that no clover had appeared either on the unfertilized plots or on those receiving nitrate of soda at the rate of 350 pounds per acre annually. It is clearly apparent that the annual application of 350 pounds of acid phosphate has been the means of securing the prolific clover development on the plots treated with this chemical either alone or combined with potash; yet when a weight of nitrate of soda equal to that of the acid phosphate was added, it completely overbalanced by the production of grasses the peculiar properties of the acid phosphate which nourishes and encourages the clover. The clover produced on the acid phosphate and acid phosphate and potash plots was cut in June, 1913, and permitted to lie where it fell when cut, composing a splendid mulch all over the surface of the plots.

In 1914, the season following the splendid production of clover, the clover plants had practically disappeared from the plots which had presented so interesting an exhibit in 1913. However, in its place there appeared as if by magic quite a fair production of timothy, redtop, bluegrass and orchard grass—the first of these

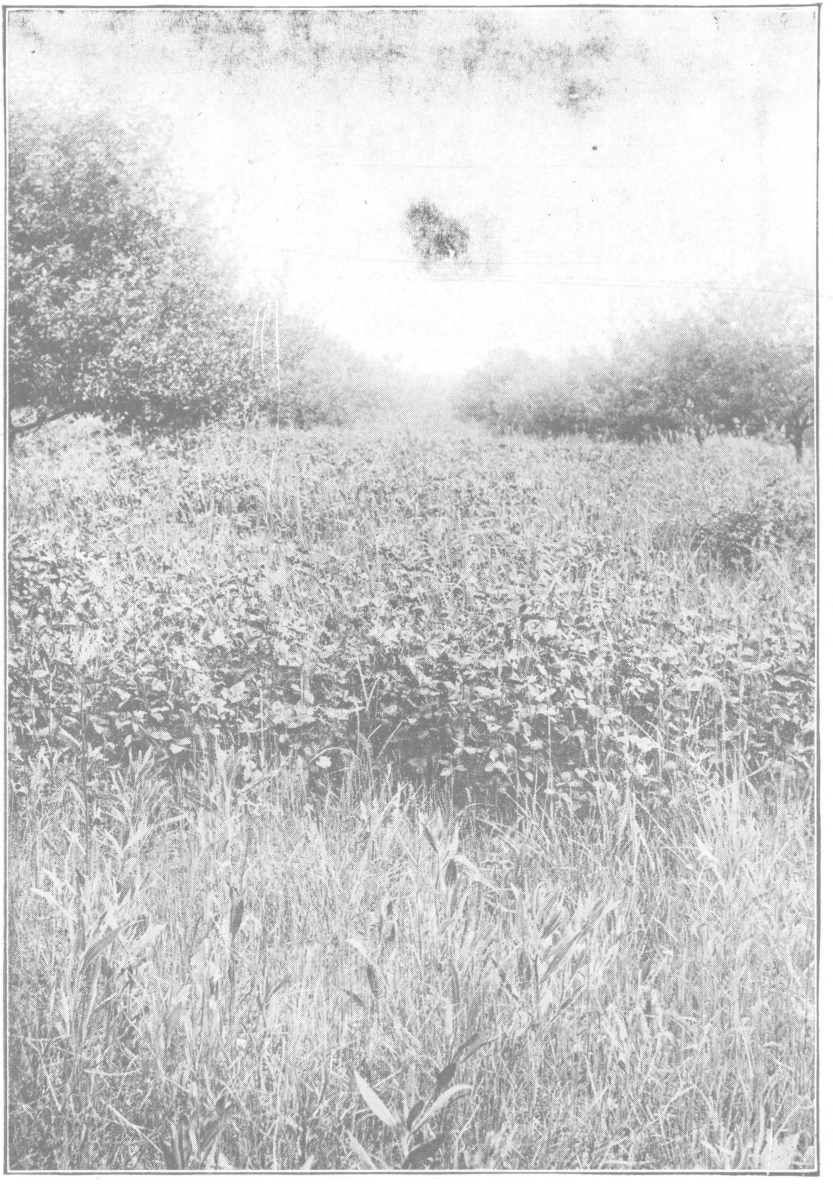


Fig. 20.—The boundary of one of the two plots in the Porter orchard at Hopewell, Muskingum County, on which acid phosphate had been applied annually at the rate of 350 pounds per acre. Compare this picture with No. 18, in which is shown the character of growth produced when 420 pounds each of nitrate of soda and acid phosphate (also 210 pounds of muriate of potash) had been used per acre.

grasses that had appeared in a noticeable degree except in the plots treated with nitrate of soda. The nitrogen extracted from the air and stored in the nodules of the roots of the clover plants, together with the decay of the root fiber and the vegetable substance of the clover mulch on the surface, provided nitrogen to which the grasses promptly responded, just as they had been doing in this and other orchard experiments from the use of nitrate of soda.

In 1915 the phosphate and phosphate-potash plots again demonstrated the constancy of the better grasses which had appeared as the clover disappeared. The wild, weedy growth such as had formerly entirely covered the orchard area and which yet covered the

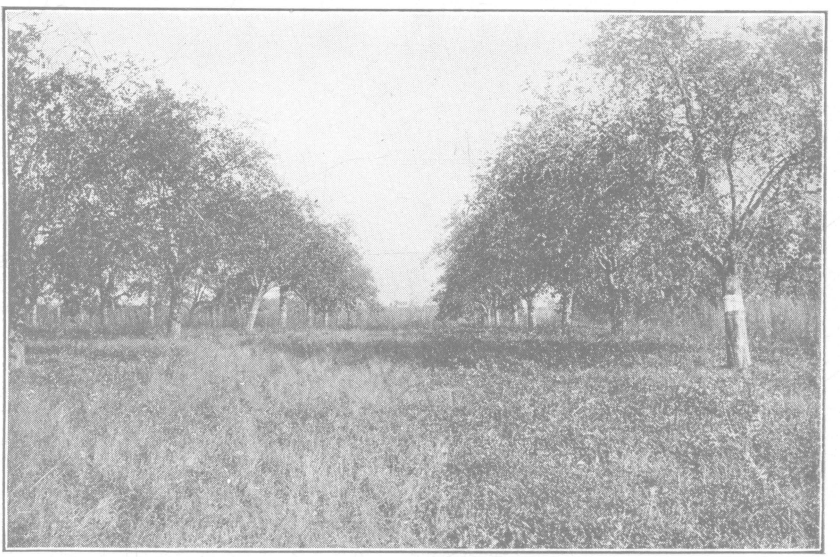


Fig. 21.—Division line between fertilized and unfertilized Rome Beauty plots in orchard at Vincent. Note the thick setting of white clover appearing on the fertilized plot at the right. This plot produced an average of nearly 40 pounds of sun-dry grasses per tree-square at the June clipping. The unfertilized plot at the left produced 4 pounds of sun-dry weeds and poverty grass.

unfertilized plots, had almost wholly disappeared. The mixture of timothy, redtop, bluegrass and orchard grass, had it not been for the corresponding increased growth of the lower-branched trees whose new shoots densely clothed with heavy foliage pushed out, shaded and considerably lessened for grass production the area of each tree-square of ground, would have equalled in bulk and weight the production of these grasses in 1914.

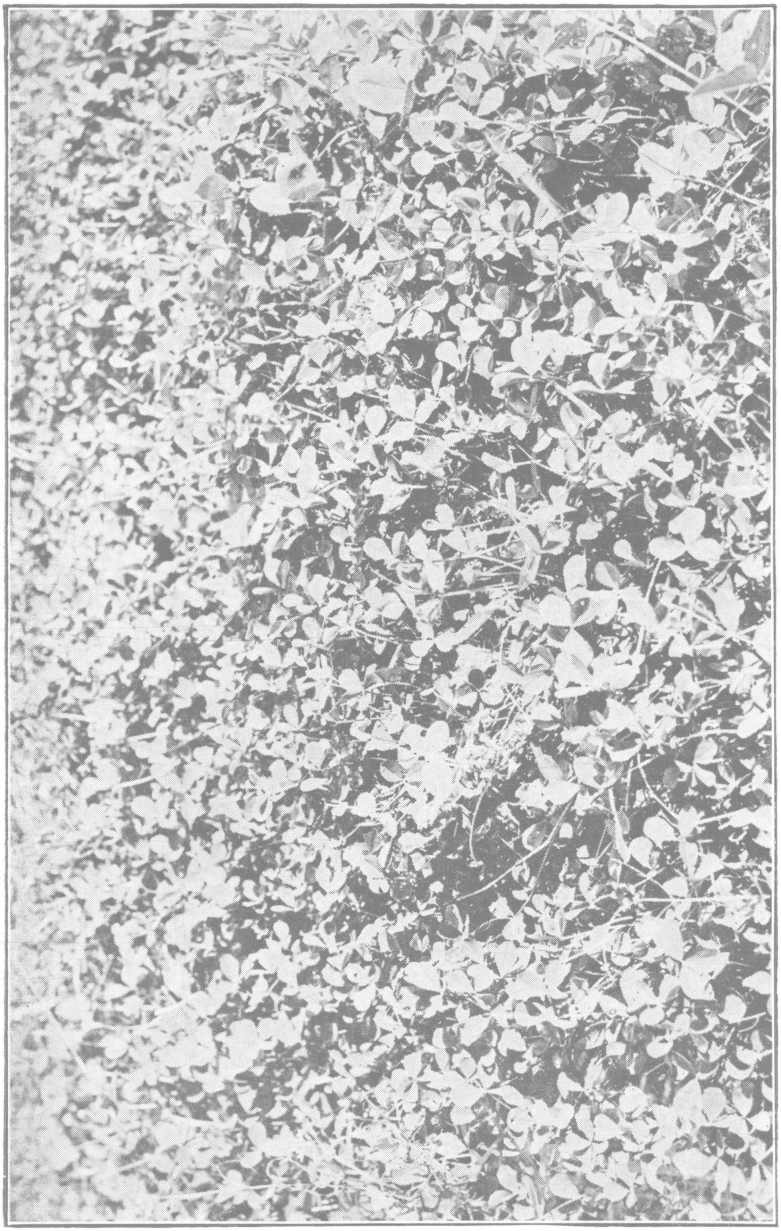


Fig. 22.—A close view in fertilized plot showing white clover.

But the most interesting development of the year 1915, in these particular plots, remains to be described. Thickly set on the ground down among the grasses and crowding these conspicuously at the time of the annual clipping in June, another and still more abundant and vigorous generation of young red clover plants was taking possession of the soil. These promise another full crop of clover for the season of 1916, which, in turn, means another generous contribution of nitrogen to the soil of the phosphate and phosphate-potash treated plots, and an effect on the orchard trees similar to the application of nitrate of soda.

Application of the lessons gained from the acid phosphate treatment.—Not until the clover had attained its maximum development, disappeared and left in connection with the decaying roots a liberal store of available nitrogen, did the apple trees situated in the plots treated with acid phosphate alone or in combination with potash, begin to show any marked improvement in wood growth, foliage development or disposition to produce fruit. In other words, these physical improvements came simultaneously with the stage of development of the clover product at which nitrogen from this legume became available to the feeding root systems of the trees. Hence this scheme of providing nitrogen as a factor in rejuvenation of neglected orchards of bearing age situated on very thin soil, is evidently too slow for practical use where prompt results in fruit production under these conditions are desirable; but the plan is entirely practicable, unusually promising and perhaps the most economical of all when so revised as to embrace the use of nitrate of soda with acid phosphate in such a way as not to stimulate the production of the various grasses named to the extent that the clover will be crowded or smothered out. In this modification of the plan of using the two chemicals named, to promote both prompt fruiting and eventual clover production as the means of supplying nitrogen for the future, the nitrate of soda may be applied in a circle beneath the outer extremities of the branches of the trees while the acid phosphate is sown evenly over the remainder of the surface of the ground among the trees. The trees, by this treatment, will respond promptly in increased vigor and fruitfulness from the influence of the nitrate applied directly over their feeding root systems, while the acid phosphate will gradually encourage the development and rotation of clover in connection with the better grasses which, through nature's provision, will alternate with the leguminous crops.

Results of lighter applications of nitrate with acid phosphate.—The results so far stated of the use of nitrate of soda and acid phosphate as affecting clover development in the orchard, refer to experiments in which these elements of plant food have been used at the rate of not less than 350 pounds per acre of each, either alone or mixed. However, in our work at Vincent and Lowell the indications are that where nitrate at a rate of not above 200 pounds in combination with acid phosphate at a rate of 200 pounds and upward per acre are applied evenly over the entire plots, we may obtain very nearly as good results from the nitrate so far as its influence on the trees and fruit production are concerned as where it is applied in a circle under the outer extremities of the branches, and without counterbalancing the beneficial effects of the phosphate in clover encouragement.

At Vincent not only did a grass-mulch plot treated with a 5-5 pounds per tree per year mixture of nitrate-phosphate sown evenly over the tree-squares, show a remarkable increase in vigor and fruitfulness of the trees, but the former growth of mixed weeds and poverty grass gave way to the more valuable grasses among which, at the close of the season of 1915—the second year of our work in this orchard—an excellent setting of white clover was rapidly taking possession of the soil. At Lowell a plot for the 2 years of 1912-13 had received, each spring, an application per tree-square of 10-10-5 pounds of the nitrate-phosphate-potash mixture. A rank growth of mixed grasses soon crowded out the thin covering of weeds formerly existing. No clover appeared in this dense growth of vegetation during these first 2 years. In 1914-15, on this plot, the nitrate was reduced just one-half, or to 5 pounds per tree-square annually—the phosphate and potash applications remaining at 10 and 5 pounds, respectively. In another adjoining plot which, in 1912-13, had received the 10-10-5 nitrate-phosphate-potash mixture, the nitrate was dropped out entirely in 1914-15. The results were that where the nitrate was reduced to 5 pounds per tree-square clover was becoming noticeable here and there during the past season of 1915, while where the nitrate was discontinued altogether and the phosphate-potash treatment maintained the white clover became very thickly set in many portions of the plot and was rapidly spreading throughout the autumn. A third plot on which the original formula of 10-10-5 pounds of the nitrate-phosphate-potash combination has been continued throughout the 4 years' work, there is scarcely a trace of clover to be found—the dense, heavy, annual

production of the various grasses rendering conditions unfavorable for clover development. No clover of any kind has appeared on the corresponding check, or unfertilized plot.

Cultivation vs. the grass-mulch method of culture.—As before stated, conditions in this orchard, so far as extremely poor soil and an advanced degree of starvation of trees were concerned, were as nearly uniform as we have been able to discover in all southeastern Ohio. Moreover, the orchard lies on so gentle a southern slope that cultivation could be carried on without serious danger of erosion—which is really unusual in that hilly section.

The orchard was divided into two plots of equal size. The southern half was plowed in the spring of 1914 and disked in the spring of 1915. The soil was occasionally harrowed each season, following the plowing and disking until June, when cowpeas were drilled in rows 2 feet apart and cultivated two or three times each season during the early stages of their growth. Both the cultivated and grass-mulch plots were fertilized exactly alike, so that the behavior of each from the effect or the application of chemical plant food might be carefully studied and compared. No mulching of straw or other vegetable matter from outside sources has been applied to either plot. The results of this fair comparison of cultivation with the grass-mulch system are practically the same, so far as dollars and cents are concerned, for the two seasons. The apples of the cultivated plot, while larger and slightly greater in yield than those from the grass-mulch plot, have been inferior in color and more expensive to produce. The average annual results per acre for 2 years' work are given in the figures which follow:

Treatment of plot	Yield	Cost of cultivation	Net returns
	Barrels	Dollars	Dollars
Cultivated	68.8	16.79	155.21
Grass-mulch	63.2	1.13	156.87
Difference in favor of the grass-mulch plot			1.66

The cost of cultivation includes plowing, disking, harrowing, seed, seeding, cultivation of cover crops and disking down cover crops in autumn. The cost of the "cultural" work in the grass-mulch plot includes clipping the grass in June and September of each season and trimming under the trees with a scythe.